MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

EEN7046 – VLSI DESIGN

5 MARCH 2016
2.30 p.m - 5.30 p.m
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Attempt **All** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Construct the truth table for the following functions.

$F1(A, B, C, D) = \Sigma m(0, 2, 3, 5, 6, 7, 8, 10, 11, 14, 15)$

$F2(A, B, C, D) = AB + \bar{C}D + A\bar{B}CD$

[8 marks]

(b) Compute the simplified characteristic equations of the function in part (a).

[8 marks]

(c) Design the functions in part (b) using programmable logic array.

[9 marks]

Continued ...

Question 2

(a) Compute the equation of the output signal, F shown in Figure 2.

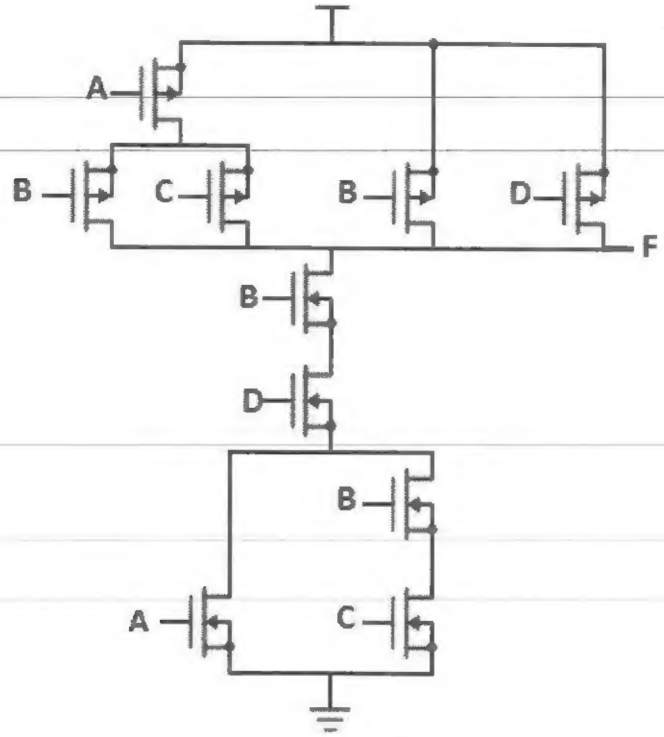

Figure 2

[2 marks]

(b) Compute the simplified characteristic equation of function F in part (a).

[4 marks]

(c) Implement the function F in part (b) using CMOS transistors.

[8 marks]

(d) Compute the W/L ratio of all the transistors used in the CMOS circuit that you draw in part (c) using 1µm CMOS technology. The transistor length must be minimum and the ratio of $\frac{[W/L]p}{[W/L]n} = 2$.

[4 marks]

(e) Design the function F in part (b) using pure NAND gates only.

[7 marks]

Continued ...

Question 3

(a) Answer the following questions regarding Early voltage, V_A in bipolar junction transistor (BJT).

(i) Define Early voltage. [2 marks]

(ii) Sketch I_C versus V_{CE} graph and identify the Early voltage in the graph. Write the collector current equation which contains Early voltage. [3 marks]

(b) Fill up the comparison of voltage gain, current gain, input resistance and output resistance for the different configuration of BJT amplifiers given in Table 3(b). [6 marks]

Table 3(b)

Configuration	Voltage gain	Current gain	Input resistance	Output resistance
Common emitter				
Emitter follower				
Common base				

(c) A multistage source follower amplifier consists of NMOS transistors is shown in Figure3(c). The transistors parameters are as follow.
$K_{n1} = K_{n2} = 150\mu A / V^2, V_{TH1} = V_{TH2} = 0.6V, \lambda_1 = \lambda_2 = 0$.

(i) Given that $V_{DS2} = 4V$. Determine the values for I_{D2}, V_{GS2}, V_{S1}, I_{D1} and V_{DS1} (by sequence). [8 marks]

(ii) Determine V_{GS1} and V_{G1}. Given that R_{in}=200kΩ. Find the appropriate values for resistor R_1 and R_2. [6 marks]

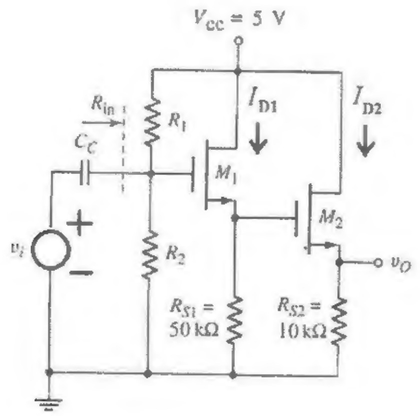

Figure 3(c)

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Question 4

(a) R-2R ladder is one of the most popular architecture of DAC architecture

(i) Sketch the circuit diagram of R-2R ladder DAC.

[5 marks]

(ii) Describe the function of the circuit based on the circuit diagram in (a)(i) above.

[4 marks]

(iii) Describe the advantage of R-2R ladder compared to weighted-resistor DAC.

[2 marks]

(iv) Write down the V_{out} equation for R-2R ladder. Given that the reference voltage, V_{ref} for the 8-bit R-2R ladder is 3V. If B_{in}=11100101, determine the output voltage of the DAC. Also find V_{LSB}.

[6 marks]

(b) The emitter coupled pair shows in Figure 4(b) has $\beta = 100$, $R_{EE} = 50\text{k}\Omega$, $r_\mu = \infty$, $r_o = \infty$, $R_C = 10\text{k}\Omega$, $I_Q = 1\text{mA}$, $V_T = 26\text{mV}$ and $V_{CC} = 15\text{V}$. Assume that $i_{C1} = i_{C2}$.

(i) Determine g_m and r_π. [3 marks]

(ii) Find the differential-mode input impedance, R_{id}. [2 marks]

(iii) Determine the differential mode gain, A_d. [3 marks]

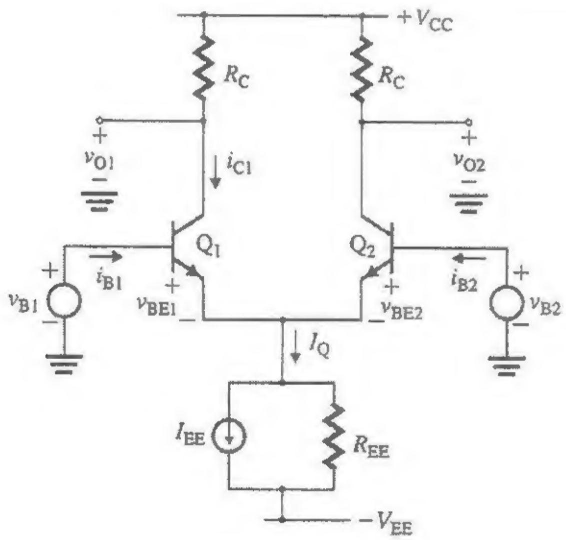

Figure 4(b)

Continued ...

Appendix: Useful formula

$$V_T = \frac{kT}{q}$$

$$I_B = \frac{I_C}{\beta_F}$$

$$I_E = \frac{-I_C}{\alpha_F}$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right)-1\right)\left(1+\frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$C_b = \tau_F g_m$$

$$r_\pi = \frac{\beta}{g_m}$$

$$r_o = 1 \Big/ \frac{\partial I_C}{\partial V_{CE}} = \frac{V_A}{I_C}$$

$$r_\mu = \beta r_o$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)\left[2(V_{GS}-V_t)V_{DS}-V_{DS}^2\right]$$

$$L_{eff} = L_{drawn} - 2L_D - X_d$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L_{eff}}\right)(V_{GS}-V_t)^2\left(1+\frac{V_{DS}}{V_A}\right)$$

r_o (BJT) = $1/\eta g_m$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$r_o = \frac{V_A}{I_D}$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}}$$

$$\frac{\partial V_t}{\partial V_{BS}} = \frac{-\gamma}{2\sqrt{2\phi_f + V_{SB}}} = -\chi$$

$$\chi = \frac{C_{js}}{C_{ox}} = \frac{g_{mb}}{g_m}$$

$$f_T = \frac{1.5\mu_n}{2\pi L^2}V_{OV}$$

$$f_T = \frac{2\mu_n}{2\pi W_B^2}V_T$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1-\exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

End of Paper